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LOW-TEMPERATURE LUBRICANTS FOR THE M134 AIRCRAFT MACHINE GUN (MINIGUN)

TECHNICAL REPORT

Fred Novekoff

February 1971

SCIENCE & TECHNOLOGY LABORATORY

RESEARCH & ENGINEERING DIRECTORATE

U. S. ARMY WEAPONS COMMAND

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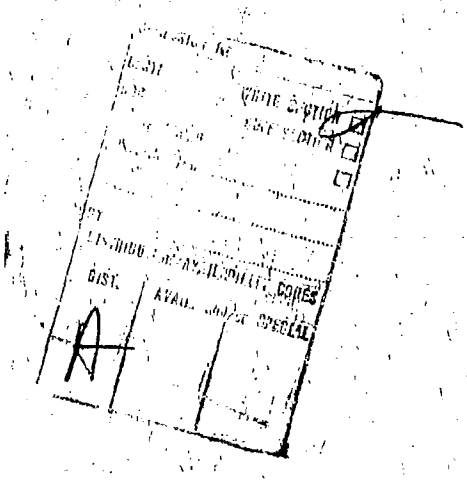

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13. ABSTRACT

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FOREWORD

This work was performed in part under Project Directive 0019V001 and AMS Code 502E.11.801, under project title "Lubricants, Friction and Wear." The subtask title was "Weapons Lubricant Field Tests." Additional work was performed under AMS Code 5142.12.11209.15, project title "Development of Aircraft Gun Type Subsystem," with work unit title "Investigate Low-Temperature Lubricants for Use with the M134 Machine Gun."

CONTENTS

OBJECTIVE

The objective of this investigation was to determine which low-temperature (0° to -65°F) lubricant should be specified for use on the M134 Aircraft Machine Gun (Minigun).

INTRODUCTION

The Science and Technology Laboratory was requested by the Aircraft Weapons Systems Laboratory (1) to investigate the possibility of using MIL-L-14107 for the M134 gun under sustained firing at temperatures below -30°F and (2) to develop a polytetrafluoroethylene (PTFE) lubricant for low temperature use.

Data were unavailable at all temperatures, and the data that were available led to conflicting recommendations on lubrication. Tests at Aberdeen Proving Ground[1] indicated that LSA-T was inadequate at -65°F. Lubrication Order 9-1005-257-12[2] recommends the use of LSA-T from above +32°F to -10°F. This recommendation conflicts with that of the Science and Technology Laboratory which recommended the use of LSA-T down to -30°F.

Firing tests were conducted in June 1969 at Eglin Air Force Base to evaluate and qualify nine LSA-T formulations received from various suppliers.[3] These formulations were tested on the Minigun at high temperature (180°F), at ambient temperature (40° to 100°F), and at low temperature (-30 to -65°F). Results of this test indicated that LSA-T is adequate to only -30°F. However, an experimental lubricant, AWC #6, performed adequately at -65°F. None of these formulations were tested under sustained firing conditions. Therefore, additional firing tests were needed.

PROCEDURE

A. Materials Used

The lubricants used in this investigation are briefly described below:

Lubricant MIL-L-14107B(LAW) is a fluid and is the authorized arctic preservative lubricant for small-arms weapons under cold-weather conditions (0° to -65°F). The

lubricating oil consists of a tetra-alkyl silicate into which additive materials have been incorporated to inhibit rust and oxidation.

Lubricant MIL-L-46150(LSA-T) is a semifluid compound with 25 per cent polytetrafluoroethylene (PTFE). This is a thickened synthetic diester lubricant with inhibitors that provide resistance to corrosion and oxidation.

Lubricant AWC #1 is a semifluid compound containing 10 per cent PTFE molding powder. This lubricant is a silicate ester thickened with lithium stearate and contains an antiwear additive, oxidation inhibitor, and a corrosion-inhibitor system, in addition to the PTFE powder.

Lubricant AWC #6 is a semifluid compound with 5 per cent PTFE added. This lubricant is a pelargonic acid ester thickened with lithium stearate, and contains an antiwear additive, oxidation inhibitor, and a corrosion-inhibitor system.

B. Weapon Used

Two Automatic Guns, 7.62MM, GAU-2B/A, mounted on Aircraft Machine Gun Module 7.62MM, Air Force Model MXU-470/A were used. The gun module drum for this weapon is capable of holding 2000 rounds. The 7.62MM Automatic Gun is an electrically driven, six-barrel, Gatling-type weapon with low (2000), medium (4000), and high (6000 rounds per minute) firing rates. It is air-cooled, can be belt- or drum-fed, and is fully automatic. The six barrels have a fixed headspace and are of the quick-change type. This weapon, commonly called the Minigun, is presently used in a helicopter armament function. The major components of this weapon are rotor assembly, six bolt assemblies, six removable track, gun housing, safing sector, housing cover, guide bar, rear gun support, six barrels, and barrel clamp.

The ammunition is a 7.62MM cartridge-linked, 4-ball; and 1-tracer M13 linked, covered by FSN 1305-926-3942-A165. The ammunition was obtained from Hill Air Force Base, Ogden, Utah, but shipped from Lexington Blue Grass Army Depot, Richmond, Kentucky.

C. Firing Tests

All firing tests were conducted with the weapons set for automatic fire at the high rate of 6,000 rounds per minute. Details of each test are outlined in the following paragraphs:

1. Firing Test at Ambient Temperature (40° to 100°F)

The weapons were disassembled and cleaned of all traces of lubricants and residues with Stoddard Solvent (PD-680 "Dry Cleaning Solvent"). The parts were then dried with the use of an air hose and moisture-free compressed air. The lubricant was then applied generously to the gun with a brush. The front and rear bearings of the weapon are lubricated with a special lubricant; these bearings were excluded from the test. After lubrication, the weapon was mounted on the stand and test fired. The two weapons were used alternately in these tests; while one was being fired, the other was being prepared for the next test. Sixteen 1,000 round-bursts were fired with each lubricant, except that the LAW was not used in this test. In each test, the weapon being fired was cooled for two minutes following each odd numbered burst and cooled to ambient temperature following each even-numbered burst. The rate of fire and the peak rate (reached within 0.5 second) were recorded. Barrel temperatures were determined for the ambient tests only. When the sixteen bursts were completed, the gun was examined for dry areas, wear, galling, carbon or other deleterious effects.

2. Firing Test at 0°F

The weapons were prepared in the same way as those for the ambient test, except for the following changes: (a) Each gun along with the ammunition was soaked at 0°F for four hours before firing. (b) The barrels were cooled to 100±10°F after each 2,000 rounds. Again, 16,000 rounds were fired for each lubricant except for LAW.

3. Firing Test at -30°F

The procedure was the same as above, except that the lubricated gun and the ammunition were soaked at -30°F for four hours before firing. Here, 16,000 rounds were fired for each lubricant, including the LAW.

4. Firing Test at -65°F

The procedure, outlined above, was again followed, except that the lubricated gun and the ammunition were soaked at -65°F for four hours. The weapon was expected to reach peak rate within 1.0 second at this temperature. Again, 16,000 rounds were fired for each lubricant.

RESULTS AND DISCUSSION

Results of the firing tests are shown in Tables I through V. LSA-T performed better than AWC #1 or AWC #6 at ambient temperature on the basis that the weapon accelerated to the highest rate in the shortest time (Table I). No significant difference is apparent in the performance between these three compounds at 0°F.

The data at -30°F (Table III) show that the AWC #1 was superior to the other three lubricants tested; based on the highest rate. MIL-L-14107 is considered unsatisfactory since jamming occurred.

At -65°F, the AWC #6 gave slightly improved performance over the AWC #1 and the LSA-T (Table IV). Again, bolts jammed when MIL-L-14107 was used.

In Table V, average firing rates and barrel temperatures are itemized under the test conditions described. The barrel temperatures were taken at every 1000-round burst so that the maximum temperature reflected the end of the second 1000-round burst before cooling to ambient temperature. This temperature varied dependent on the type of day. The firing rate was also taken at every burst and reflects the average peak firing rates. Since the feed ammunition module held 2000 rounds, the load affected the firing rate. Current requirements for the rate of fire are based on a 100-round belt load which requires 6000 rounds per minute. This accounts for the lower firing rates recorded.

The Minigun, lubricated with MIL-L-14107, malfunctioned 3 times in 277 rounds (Table III footnote). To prove whether the malfunctions were caused by the lubricant, LSA-T was applied liberally to the rotor and bolts. The remainder of a 2000-round complement, or 1723 rounds, was fired in two bursts without a malfunction. MIL-L-14107 lubricant was then tried at -65°F. The bolts jammed at 57, 100, and 400 rounds (Table IV footnote). The gun was then removed and no further testing was conducted on MIL-L-14107. Recent lubricant friction and durability tests[4] under simulated weapon conditions at ambient temperature also show that LAW has little or no lubricating ability compared with LSA-T.

TABLE I

ACCELERATION AND FIRING RATES AT AMBIENT TEMPERATURE

	Firing Rate, rounds/minute		
Time, second	LSA-T *	AWC #1 **	AWC #6 ***
0.1	3514	3621	3736
0.2	5014	4621	4814
0.3	5657	5207	5242
0.4	6171	5478	5385
0.5	6271	5521	5407
0.6	6271	5521	5492
0.7	6271	5521	5529
0.8	6271	5521	5579
0.9	6271	5521	5621
1.0	6271	5521	5621

*-Barrel temperature after 1,000-round burst: 920°F
**-Barrel temperature after 1,000-round burst: 980°F
***-Barrel temperature after 1,000-round burst: 1080°F

TABLE II

ACCELERATION AND FIRING RATES AT 0°F

Time, second	Firing Rate, rounds/minute		
	LSA-T	AWC #1	AWC #6
0.1	4221	4038	4108
0.2	5614	5638	6092
0.3	6179	6323	6446
0.4	6386	6469	6500
0.5	6436	6554	6546
0.6	6493	6554	6546
0.7	6514	6554	6546
0.8	6529	6554	6546
0.9	6543	6554	6546
1.0	6543	6554	6546

TABLE III

ACCELERATION AND FIRING RATES AT -30°F

	Firing Rate, rounds/minute			
Time, second	*MIL-L-14107	LSA-T	AWC #1	AWC #6
0.1	3000	3950	4200	3900
0.2	3900	4700	6300	5100
0.3	5400	5750	6450	5700
0.4	5800	6200	6600	6090
0.5	5900	6200	6700	6090
0.6	--	6200	6700	6090
0.7	--	6200	6700	6090
0.8	--	6200	6700	6090
0.9	--	6200	6700	6090
1.0	--	6200	6700	6090

*Malfunctions - bolts jammed after 120, 112, and 45 rounds in three trials

TABLE IV

ACCELERATION AND FIRING RATES AT -65°F

Time, second	Firing Rate, rounds/minute			
	*MIL-L-14107	LSA-T	AWC #1	AWC #6
0.1	3000	3757	4050	3450
0.2	5200	4886	5400	5100
0.3	5700	5443	5850	5850
0.4	5800	5471	5900	5850
0.5	--	5529	5900	6000
0.6	--	5629	5900	6000
0.7	--	5743	5900	6000
0.8	--	5743	5900	6000
0.9	--	5743	5900	6000
1.0	--	5743	5900	6150

*Malfunctions - bolts jammed after 57, 100, and 400 rounds in three trials

TABLE V

AVERAGE FIRING RATES AND BARREL TEMPERATURES

Lubricant	Barrel Temp., °F	Firing Rate/ rounds/minute			
		Ambient	0°F	-30°F	-65°F
AWC #1	880 - 1080	5500	6520	6590	5625
AWC #6	810 - 960	5690	6700	5880	5850
LSA-T	900 - 910	5914	6460	6125	5640
MIL-L-14107	---	No Test	No Test	*	*

*Malfunctions occurred. Bolts jammed because of deficient lubrication.

CONCLUSIONS AND RECOMMENDATIONS

Based upon the tests conducted, MIL-L-14107B lubricant cannot be recommended for use at any temperature on the 7.62MM Automatic Gun GAU-2B/A, known as the Minigun. MIL-L-46150(LSA-T) can be used from ambient temperature to -30°F. Lubricant AWC #1 or AWC #6 can be used satisfactorily from 0° to -65°F on this weapon.

It is recommended that a purchase description be prepared establishing requirements and test procedures for Experimental Lubricants AWC #1 or AWC #6. This document will make the materials readily available within the military supply system.

LITERATURE CITED

1. Steier, G. M., "Final Report on Comparison Test of Pod, Aircraft Gun 7.62MM, XM18E1 (Quality Assurance)," Aberdeen Proving Ground Report APG-MT-3431, January 1970.

2. "Armament Pod, Aircraft, 7.62 Millimeter Machine Gun: XM18 and XM18E1," Lubrication Order LO9-257-12, 10 October 1969.

3. Novekoff, F., "RIAPD-688 Lubricant, Semifluid Low Friction (Automatic Weapons) for Automatic 7.62MM, GAU-2B/A," U. S. Army Weapons Command Science and Technology Laboratory Technical Report , in preparation.

4. Bornong, B. J., "Lubricant Friction and Durability Tests Under Simulated Weapon Conditions," U. S. Army Weapons Command Science and Technology Laboratory Technical Report RE-70-190, November 1970.

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